

1 CLAIMS  
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3 What is claimed is:

1       1. A method for performing concurrent mark-sweep garbage collection,  
2 comprising:  
3       receiving an application;  
4       executing the application in at least one thread;  
5       determining if available space in a heap falls below a threshold;  
6       performing mark-sweep garbage collection, concurrently while executing  
7 the application, in a heap block of the heap using a first bit vector, a second bit  
8 vector, a mark bit vector pointer, and a sweep bit vector pointer in the heap  
9 block, if the available space falls below the threshold; and otherwise,  
10       continuing executing the application and monitoring if the available space  
11 in the heap falls below the threshold, until the execution of the application is  
12 complete.

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1       2. The method of claim 1, wherein the heap comprises at least one heap  
2 block.

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1       3. The method of claim 1, further comprising initializing a concurrent  
2 mark-sweep garbage collector.

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1       4. The method of claim 3, wherein initializing the concurrent mark-sweep  
2 garbage collector comprises setting each bit in the first bit vector and the second  
3 bit vector to 0, and pointing the mark bit vector pointer to the first bit vector and  
4 the sweep bit vector pointer to the second bit vector.

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1       5. The method of claim 1, wherein performing mark-sweep garbage  
2 collection comprises:

3       invoking at least one garbage collection thread to trace live objects in the  
4 heap block concurrently while executing the application; and

5 reclaiming storage space occupied by objects other than the live objects  
6 in the block concurrently while tracing the live objects in the block and executing  
7 the application.

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1 6. The method of claim 5, wherein tracing the live objects in the heap  
2 block comprises parallel marking the live objects by at least one garbage  
3 collection thread.

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1 7. The method of claim 6, wherein parallel marking the live objects  
2 comprises setting bits corresponding to starting addresses of the live objects in a  
3 bit vector pointed to by the mark bit vector pointer to 1, by the at least one  
4 garbage collection thread.

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1 8. The method of claim 5, wherein reclaiming the storage space occupied  
2 by objects other than the live objects in the heap block comprises sweeping the  
3 heap block to make the said storage space allocable by using a bit vector  
4 pointed to by the sweep bit vector pointer.

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1 9. The method of claim 6, further comprising toggling a bit vector pointed  
2 to by the mark bit vector pointer with a bit vector pointed to by the sweep bit  
3 vector pointer after marking the live objects in the heap block is complete.

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1 10. The method of claim 8, further comprising setting the bit vector back  
2 to 0 after completing sweeping the heap block.

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1 11. The method of claim 1, further comprising performing another cycle of  
2 concurrent mark-sweep garbage collection when available space in the heap  
3 falls below the threshold again.

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1 12. A method for automatically collecting garbage objects, comprising:  
2 receiving a first code;

3       compiling the first code into a second code;  
4       executing the second code in at least one thread; and  
5       automatically performing mark-sweep garbage collection using bit vector  
6       toggling, concurrently with the executing second code, to ensure there is storage  
7       space available for executing the second code.

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1       13. The method of claim 12, wherein automatically performing mark-  
2       sweep garbage collection using bit vector toggling comprises detecting if  
3       available space in a heap falls below a threshold and invoking the concurrent  
4       mark-sweep garbage collection when the available space falls below the  
5       threshold.

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1       14. The method of claim 13, wherein the heap comprises at least one  
2       heap block.

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1       15. The method of claim 13, further comprising using two bit vectors for a  
2       heap block, one for marking and the other for sweeping, and toggling the two bit  
3       vectors after marking phase for the heap block is complete.

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1       16. A system for concurrent mark-sweep garbage collection, comprising:  
2           a root set enumeration mechanism to enumerate references to live  
3           objects in a heap;

4           a live object tracing mechanism to parallel trace live objects in a heap  
5           block and mark the live objects in a first bit vector pointed to by a mark bit vector  
6           pointer in the heap block, concurrently with execution of an application; and

7           a garbage sweeping mechanism to sweep storage space occupied by  
8           garbage objects to make the storage space allocable using a second bit vector  
9           pointed to by a sweep bit vector pointer in the heap block, concurrently with the  
10          execution of the application and live object marking.

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1           17. The system of claim 16, further comprising a bit vector toggling  
2 mechanism to toggle the first bit vector pointed to by the mark bit vector pointer  
3 and the second bit vector pointed to by the sweep bit vector pointer in the heap  
4 block.

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1           18. The system of claim 16, wherein the live object tracing mechanism  
2 comprises:

3           a live object search mechanism to parallel search live objects in a heap  
4 block by at least one garbage collection thread;

5           a live object marking mechanism to parallel mark the live objects in a bit  
6 vector stored in the heap block by the at least one garbage collection thread;

7           a live object scanning mechanism to parallel scan any objects reachable  
8 from the live objects in the heap; and

9           a conflict prevention mechanism to prevent more than one garbage  
10 collection thread from marking the same object.

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1           19. A managed runtime system, comprising:

2           a just-in-time compiler to compile an application into a code native to an  
3 underlying computing platform;

4           a virtual machine to execute the application; and

5           a garbage collector to trace live objects, mark the live objects in a first bit  
6 vector pointed to by a mark bit vector pointer in a heap block of a heap, and  
7 toggle the bit first vector pointed to by the mark bit vector pointer with a second  
8 bit vector pointed to by a sweep bit vector pointer at the end of marking phase,  
9 concurrently with execution of the application.

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1           20. The system of claim 19, further comprising a garbage sweeping  
2 mechanism to sweep storage space occupied by garbage objects to make the  
3 storage space allocable using a bit vector pointed to by the sweep bit vector  
4 pointer, concurrently with the execution of the application and live objects  
5 marking.

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1        21. The system of claim 19, wherein the garbage collector comprises:  
2            a live object marking mechanism to parallel mark the live objects in the  
3 first bit vector pointed to by the mark bit vector in the heap block of the heap; and  
4            a bit vector toggling mechanism to toggle the first bit vector pointed to by  
5 the mark bit vector pointer and the second bit vector pointed to by the sweep bit  
6 vector pointer.

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1        22. A computer-readable medium having stored thereon a data structure  
2 comprising:

3            a first field containing a first pointer pointing to a mark bit vector in a heap  
4 block of a heap;

5            a second field containing a second pointer pointing to a sweep bit vector  
6 in the heap block;

7            a third field containing a first bit vector representing at least one of  
8 marking and sweeping statuses of objects stored in the heap block; and

9            a fourth field containing a second bit vector representing at least one of  
10 marking and sweeping statuses of objects stored in the heap block.

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1        23. The computer-readable medium of claim 22, wherein the data  
2 structure is stored in a header area of the heap block of the heap.

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1        24. The computer-readable medium of claim 22, wherein the first pointer  
2 is initially pointed to the first bit vector and the second pointer is initially pointed  
3 to the second bit vector, when garbage collector is initialized; and the first bit  
4 vector and the second bit vector are toggled after the heap block is marked.

1        25. An article comprising: a machine accessible medium having content  
2 stored thereon, wherein when the content is accessed by a processor, the  
3 content provides for performing concurrent mark-sweep garbage collection by:  
4            receiving an application;  
5            executing the application in at least one thread;

6       determining if available space in a heap falls below a threshold;  
7       performing mark-sweep garbage collection, concurrently while executing  
8   the application, in a heap block of the heap using a first bit vector, a second bit  
9   vector, a mark bit vector pointer, and a sweep bit vector pointer in the heap  
10   block, if the available space falls below the threshold; and otherwise,  
11       continuing executing the application and monitoring if the available space  
12   in the heap falls below the threshold, until the execution of the application is  
13   complete.

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1       26. The article of claim 25, wherein the heap comprises at least one heap  
2   block.

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1       27. The article of claim 25, further comprising content for initializing a  
2   concurrent mark-sweep garbage collector.

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1       28. The article of claim 27, wherein content for initializing the concurrent  
2   mark-sweep garbage collector comprises content for setting each bit in the first  
3   bit vector and the second bit vector to 0, and pointing the mark bit vector pointer  
4   to the first bit vector and the sweep bit vector pointer to the second bit vector.

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1       29. The article of claim 25, wherein content for performing mark-sweep  
2   garbage collection comprises content for:

3       invoking at least one garbage collection thread to trace live objects in the  
4   heap block concurrently while executing the application; and

5       reclaiming storage space occupied by objects other than the live objects  
6   in the block concurrently while tracing the live objects in the block and executing  
7   the application.

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1       30. The article of claim 29, wherein content for tracing the live objects in  
2   the heap block comprises content for parallel marking the live objects by at least  
3   one garbage collection thread.

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1           31. The article of claim 30, wherein content parallel marking the live  
2 objects comprises content for setting bits corresponding to starting addresses of  
3 the live objects in a bit vector pointed to by the mark bit vector pointer to 1, by  
4 the at least one garbage collection thread.

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1           32. The article of claim 29, wherein content for reclaiming the storage  
2 space occupied by objects other than the live objects in the heap block  
3 comprises content sweeping the heap block to make the said storage space  
4 allocable by using a bit vector pointed to by the sweep bit vector pointer.

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1           33. The article of claim 30, further comprising content for toggling a bit  
2 vector pointed to by the mark bit vector pointer with a bit vector pointed to by the  
3 sweep bit vector pointer after marking the live objects in the heap block is  
4 complete.

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1           34. The article of claim 32, further comprising content for setting the bit  
2 vector back to 0 after completing sweeping the heap block.

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1           35. The article of claim 25, further comprising content performing another  
2 cycle of concurrent mark-sweep garbage collection when available space in the  
3 heap falls below the threshold again.

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1           36. An article comprising: a machine accessible medium having content  
2 stored thereon, wherein when the content is accessed by a processor, the  
3 content provides for automatically collecting garbage objects by:  
4           receiving a first code;  
5           compiling the first code into a second code;  
6           executing the second code in at least one thread; and  
7           automatically performing mark-sweep garbage collection using bit vector  
8           toggling, concurrently with the executing second code, to ensure there is storage  
9           space available for executing the second code.

1       37. The article of claim 36, wherein content for automatically performing  
2 mark-sweep garbage collection using bit vector toggling comprises content for  
3 detecting if available space in a heap falls below a threshold and invoking the  
4 concurrent mark-sweep garbage collection when the available space falls below  
5 the threshold.

1       38. The article of claim 37, wherein the heap comprises at least one heap  
2 block.

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1       39. The article of claim 37, further comprising content for using two bit  
2 vectors for a heap block, one for marking and the other for sweeping, and  
3 toggling the two bit vectors after marking phase for the heap block is complete.